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INSTRUCTIONS FOR USE OF NON-DISCRETE AND QUASISTATIC DIAPHRAGM PRESSURE GAGES

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EDWARD J. HORWATH

DECEMBER 1988

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U.S. ARMY LABORATORY COMMAND

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This report presents Instructions for Use of both Non-Discrete and Diaphragm Pressure Gages for blast overpressure measurement. Figures are presented from which peak blast pressure may be calculated based on deformation or rupture of thin aluminum foils.

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1.0 INTRODUCTION

The Ballistics Research Laboratory (BRL) at Aberdeen Proving Ground (APG) has developed two diaphragm pressure gages for use in measuring shock and quasi-static overpressure during severe test conditions. Plans for the construction of a Non-Discrete Diaphragm Pressure Gage (NDDPG) from 1/8-in. and 3/4-in. mild steel and calibrated aluminum foil are presented (Figures 1 and 2), along with calibration curves developed for use with a range of expected shock overpressure values and foil thicknesses (Figures 3-11). Plans for the construction of a Quasi-Static Diaphragm Pressure Gage (QSDPG) from 1/8-in. and 3/4-in. mild steel and calibrated aluminum foil are presented (Figures 12 and 13), along with calibration curves developed for use with a range of expected quasi-static overpressure values and foil thicknesses (Figure 14).

2.0 OPERATING INSTRUCTIONS NON-DISCRETE PRESSURE GAGE (NDDPG)

2.1 Selection of Foil. An estimate of expected maximum shock overpressure determines the appropriate foil thickness. Using previous experimental data, estimate an expected maximum overpressure. Select a calibration curve (Figures 3-11) that incorporates an overpressure range approximately 10 to 25 percent greater than the estimate. Install, in the NDDPG, the foil correlated with the chosen calibration curve. Please note that any new foil must be pure, annealed aluminum and must be calibrated before using (1).

2.2 Installation of Foil. The appropriate thickness of foil is sandwiched between the pressure gage calibration plate and resonating chamber (see Figure 1, end view, and Figure 2 for details). The calibration plate also serves as a cover plate for the pressure gage. Remove the cover plate, placing the desired thickness of foil over the chamber. Using a sharp instrument, such as an awl or an ice pick, punch holes in the foil to align with the screw holes in the cover plate. Replace the screws, taking care to keep the foil intact.

2.3 Attachment of Gage Housing to Gage Mount. The gage is mounted on a paddle-type gage mount for experimental use. Insert the screws completely through the gage housing and back cover plate before attaching it to the mount. Verify that the chamber behind the foil is covered by either the back plate or the gage mount paddle. The back plate may be omitted when a solid-paddle gage mount is used.

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2.4 Protecting Foil. To protect the installed foil leaf from perforation or soil, place a stiff cardboard square over the foil and attach it with rubber bands.

2.5 Gage Orientation for Blast Experiment in/on a Compartment. The NDDPG can be oriented for compartmented detonation, explosive or shaped charge detonation, and omnidirectional blast pressure measurement.

2.5.1 Small Charge Detonated Inside Compartment. The NDDPG permits either face-on or side-on orientation of the foil with respect to shock propagation inside a test compartment. For face-on orientation, place the gage inside the compartment with the normal-to-foil surface pointing in the direction of the charge center or with the foil-normal plane parallel to the direction of propagation of the initial shock of the blast. For side-on orientation, place the gage inside the compartment with the plane of the foil surface passing through the charge center or with the foil plane parallel to the direction of propagation of the initial shock.

2.5.2 Explosive or Shaped Charge Detonated or Impacting Outside Compartment. The NDDPG permits either face-on or side-on orientation of the foil with respect to shock propagation outside a test compartment at one of its walls. For face-on orientation, prepare a hole through the wall to be affected by the explosive or shaped charge. Place the gage inside the compartment with the normal-to-foil surface pointing in the direction of the entrance of the hole. Alternatively, place the gage inside the compartment with the normal-to-foil surface parallel to the direction of propagation of the initial shock. For side-on orientation, place the gage inside the compartment with the plane of the foil surface parallel to the direction of propagation of initial shock.

2.5.3 Omnidirectional Gage Placement. The NDDPG permits omnidirectional measurement of peak blast or shock overpressure using side-on calibration curves. Place the gage in the compartment wall with the foil surface parallel to and flush with the interior surface of the compartment. The initial shock wave travels across the foil surface like an oblique wave or mach stem.

2.6 Gage Orientation for Blast Experiment in Open Area. The NDDPG can be oriented to measure the detonation pressure of an explosive charge in an open area. For face-on orientation, place the gage with the normal-to-foil surface pointing in the direction of the charge center or with the foil-normal plane parallel to the direction of propagation of the initial shock. For side-on orientation, place the gage with the plane of the foil surface passing through the charge center. Alternatively, place the gage with the foil plane parallel to the direction of propagation of the initial shock.

2.7 Auxiliary Equipment. Measuring peak blast or shock overpressure requires the use of a depth-gage micrometer and a recording form.

2.8 Deformation Measurement. Measuring peak blast or shock overpressure is a three-step process. First, place the micrometer on the scale surface of the gage housing, positioning it at the point of maximum deformation depth or maximum opening. If the foil is not concave at the point of maximum depth or maximum opening, push the foil down to a configuration where permanent deformation is not altered. Second, measure the depth (D) from the scale surface. Finally, subtract the cover plate thickness (T) from measured depth (D) to obtain permanent deformation depth (PD). Please note that no quasi-static pressure can be determined if the foil ruptures. Therefore, a pressure range should be determined that eliminates the potential for rupture.

2.9 Rupture Measurement. Measuring peak blast or shock overpressure when the NDDPG foil has ruptured makes use of the scale increments on its cover plate (Figure 1). Count the number of scale markings from the point of maximum opening (i.e., the initial scale mark) to the end of the rupture, moving in the direction of the cone vertex.

2.10 Peak Overpressure Values. Determining peak overpressure value for a given blast requires the use of an appropriate calibration curve. Choose the curve (A, B1, B2, B3, C1, C2, C3, D, or E) corresponding to the thickness of the foil used and the orientation of the foil (face-on or side-on) to the propagating wave. See Table 1 for a summary of calibration curve parameters.

2.11 Calibration Curves.

2.11.1 Calibration Curve "A." Choose calibration curve "A" to determine face-on overpressure from observed side-on overpressure. It correlates face-on with side-on overpressure (Figure 3).

2.11.2 Calibration Curve "B1." Choose calibration curve "B1" to determine side-on overpressure for determination or rupture with .0005-in. foil. It correlates side-on overpressure with deformation (or rupture) for .0005-in. foil, with the plane of the foil oriented normal to the direction of propagation of the initial shock (Figure 4).

2.11.3 Calibration Curve "B2." Choose calibration curve "B2" to determine side-on overpressure with .0005-in. foil when rupture occurs. This curve correlates side-on overpressure with rupture for .0005-in. foil, the plane of the foil oriented normal to the direction of propagation of the initial shock (Figure 5).

2.11.4 Calibration Curve "B3." Choose calibration curve "B3" to determine side-on overpressure with .0005-in. foil when only deformation occurs. This curve correlates side-on overpressure with deformation for .0005-in. foil, with the plane of the foil oriented normal to the direction of propagation of the initial shock (Figure 6).

2.11.5 Calibration Curve "C1." Choose calibration curve "C1" to determine side-on overpressure for deformation of rupture with .001-in. foil. This curve correlates side-on overpressure with deformation or rupture for .001-in. foil, with the plane of the foil oriented normal to the direction of propagation of the initial shock (Figure 7).

2.11.6 Calibration Curve "C2." Choose calibration curve "C2" to determine side-on overpressure when rupture occurs. This curve correlates side-on overpressure with rupture for .001-in. foil, with the plane of the foil oriented normal to the direction of propagation of the initial shock (Figure 8).

2.11.7 Calibration Curve "C3." Choose calibration curve "C3" to determine side-on overpressure when only deformation occurs. This curve correlates side-on overpressure with deformation for .001-in. foil, with the plane of the foil oriented normal to the direction of propagation of the initial shock (Figure 9).

2.11.8 Calibration Curve "D." This curve correlates side-on overpressure with deformation for .003-in. foil (Figure 10). Use curve labeled "side-on" when the foil plane is to be oriented parallel to the direction of propagation of the initial shock. Use curve labeled "face-on" when the foil plane is to be oriented normal to the direction of propagation of the initial shock.

2.11.9 Calibration Curve "E." This curve correlates side-on overpressure with deformation for .005-in. foil (Figure 11). Use curve labeled "side-on" when the foil plane is to be oriented parallel to the direction of propagation of the initial shock. Use curve labeled "face-on" when the foil plane is to be oriented normal to the direction of propagation of the initial shock.

TABLE 1

Summary of Calibration Curve Derivation and Use

CALIBRATION CURVE DESIGNATION	CALIBRATION	DETERMINATION
A	Face-On vs. Side-On Overpressure	Face-On Overpressure from Observed Side-On Overpressure
B1	Side-On Overpressure vs. Deformation or Rupture; .0005-in. Foil in Normal Plane	Side-On Overpressure .0005-in. Foil Deformation or Rupture
B2	Side-On Overpressure vs. Rupture; .0005-in. Foil in Normal Plane	Side-On Overpressure .0005-in. Foil when Rupture Occurs
B3	Side-On Overpressure vs. Deformation; .0005-in. Foil in Normal Plane	Side-On Overpressure .0005-in. Foil Deformation Only
C1	Side-On Overpressure vs. Deformation or Rupture; .001-in. Foil in Normal Plane	Side-On Overpressure .001-in. Foil Deformation or Rupture
C2	Side-On Overpressure vs. Rupture; .001-in. Foil in Normal Plane	Side-On Overpressure When Rupture Occurs
C3	Side-On Overpressure vs. Deformation; .001-in. Foil in Normal Plane	Side-On Overpressure Deformation Only
D	Side-On Overpressure vs. Deformation; .003-in. Foil	With Foil Labeled "Side-On" for Plane Parallel to Shock With Foil Labeled "Face-On" for Normal Plane
E	Side-On Overpressure vs. Deformation; .005-in. Foil	With Foil Labeled "Side-On" For Plane Parallel to Shock With Foil Labeled "Face-On" for Normal Plane

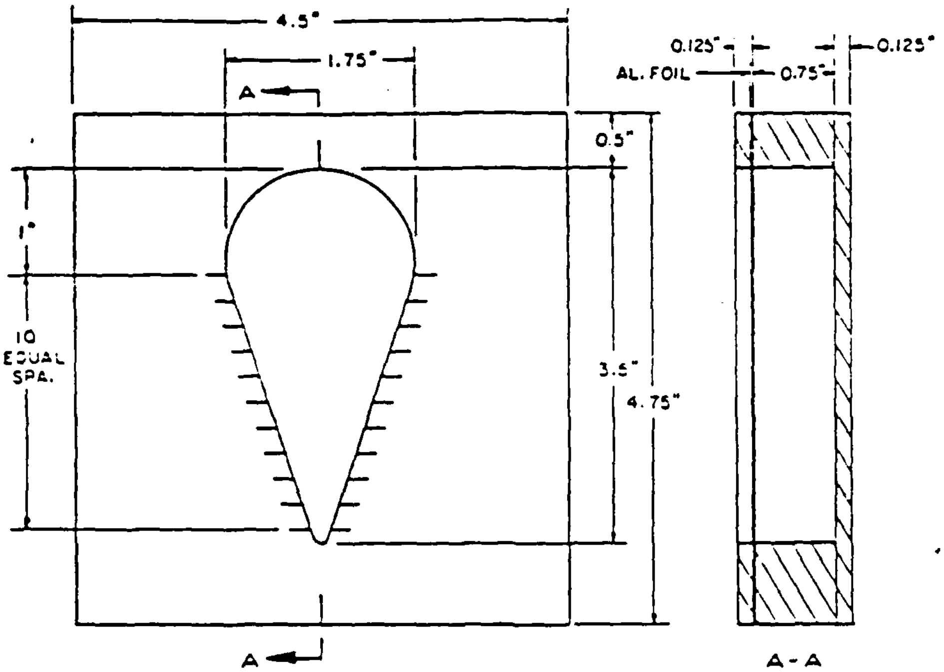

Figure 1. End View--Non-Discrete Diaphragm Pressure Gage (NDDPG).

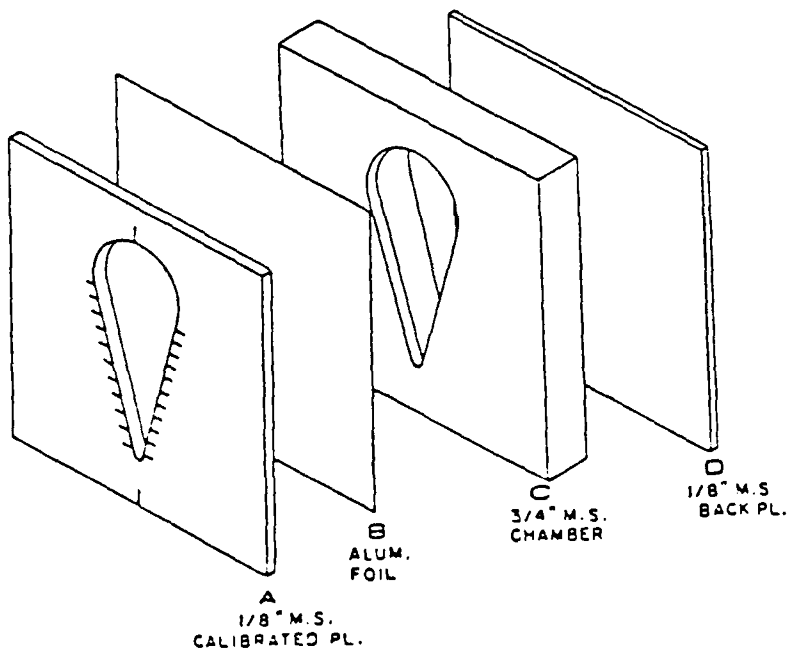

Figure 2. (U) Construction Plan View of the Non-Discrete Diaphragm Pressure Gage (NDDPG).

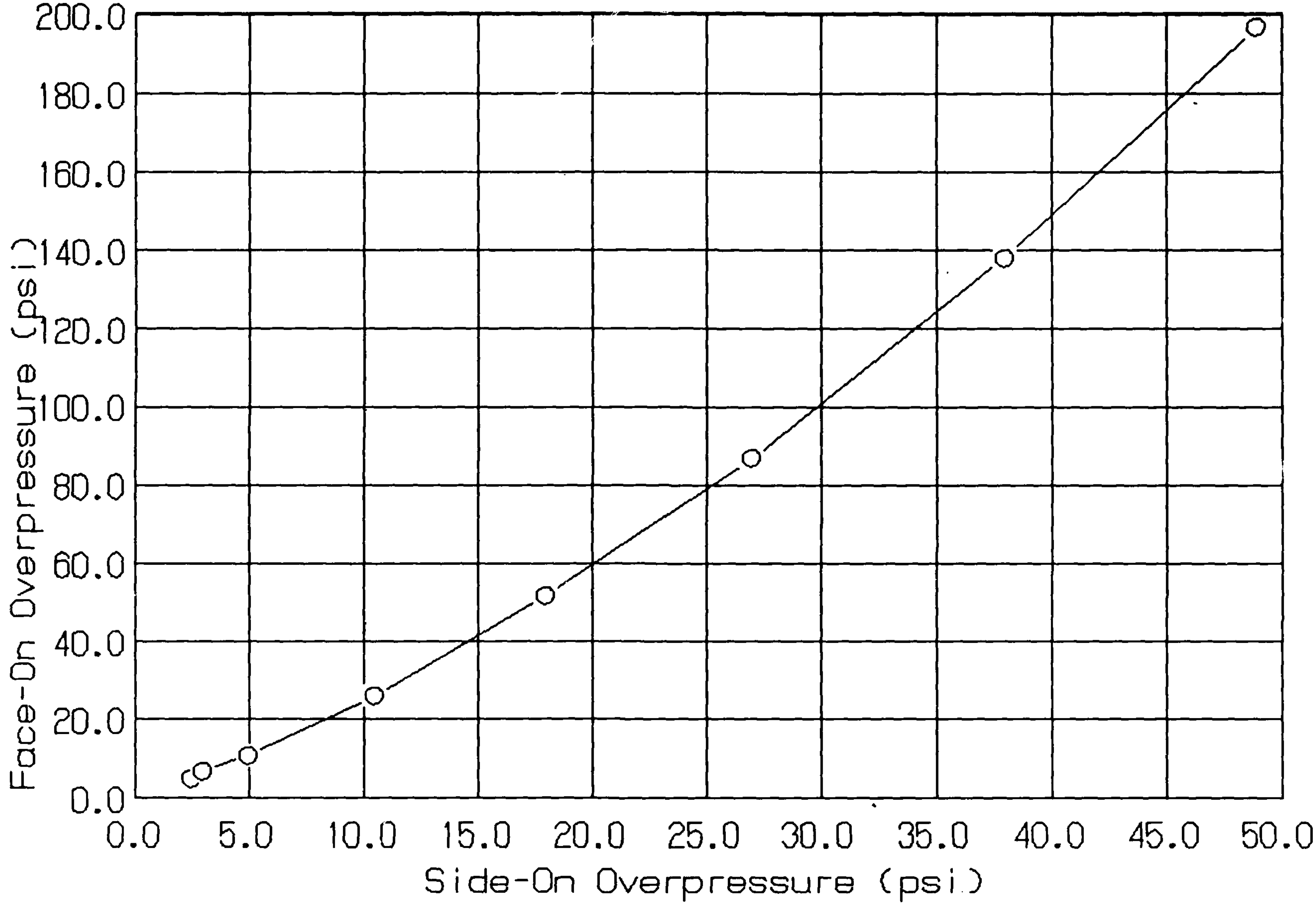

Figure 3. (U) CORRELATION CURVE A
Face-On versus Side-On Overpressure

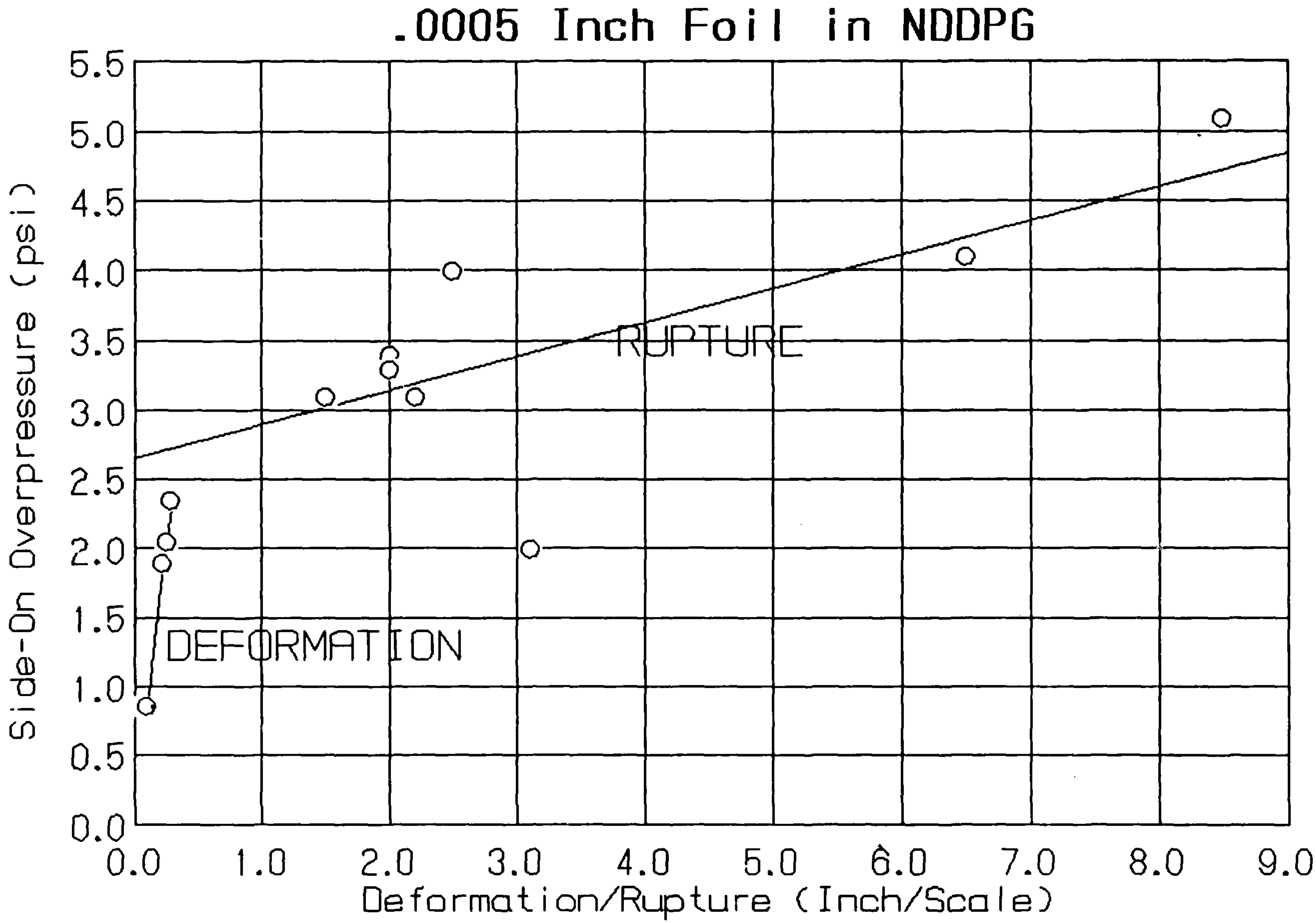

Figure 4. (U) CORRELATION CURVE B-1
Side-On Overpressure versus Deformation or Rupture

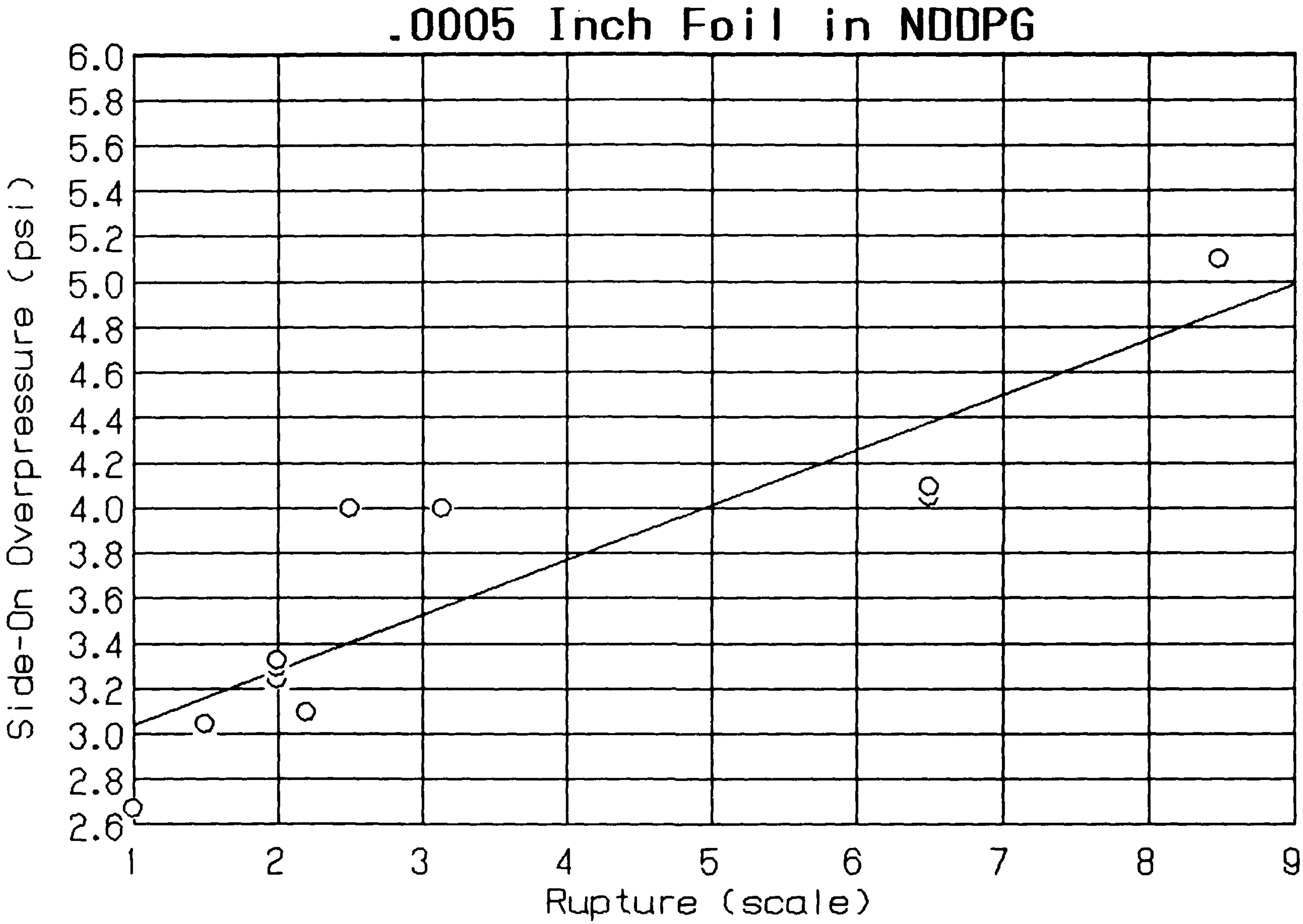

Figure 5.(U) CORRELATION CURVE B-2
Side-On Overpressure versus Rupture

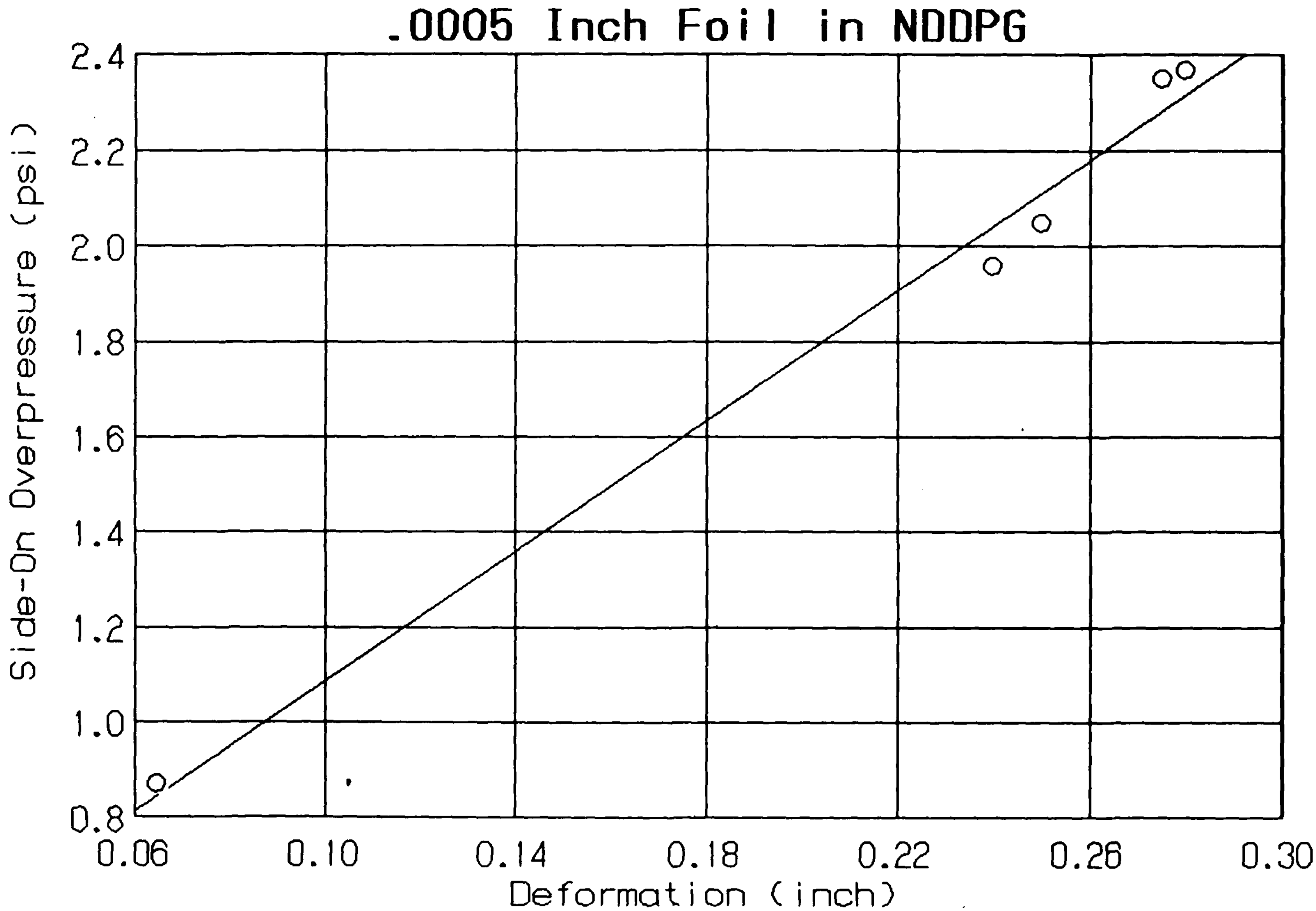

Figure 6.(U) CORRELATION CURVE B-3
Side-On Overpressure versus Deformation

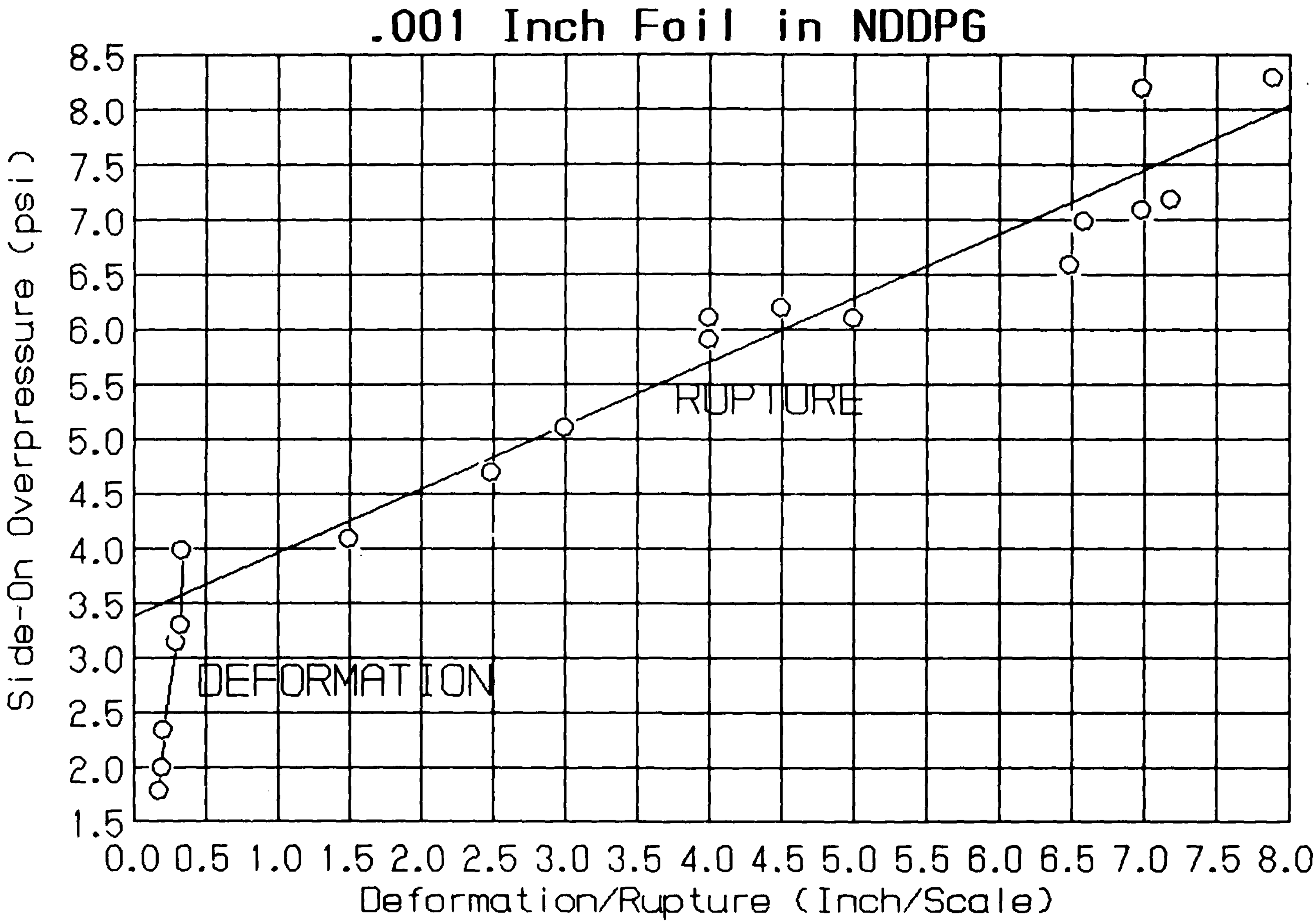

Figure 7. (U) CORRELATION CURVE C-1
Side-On Overpressure versus Deformation or Rupture

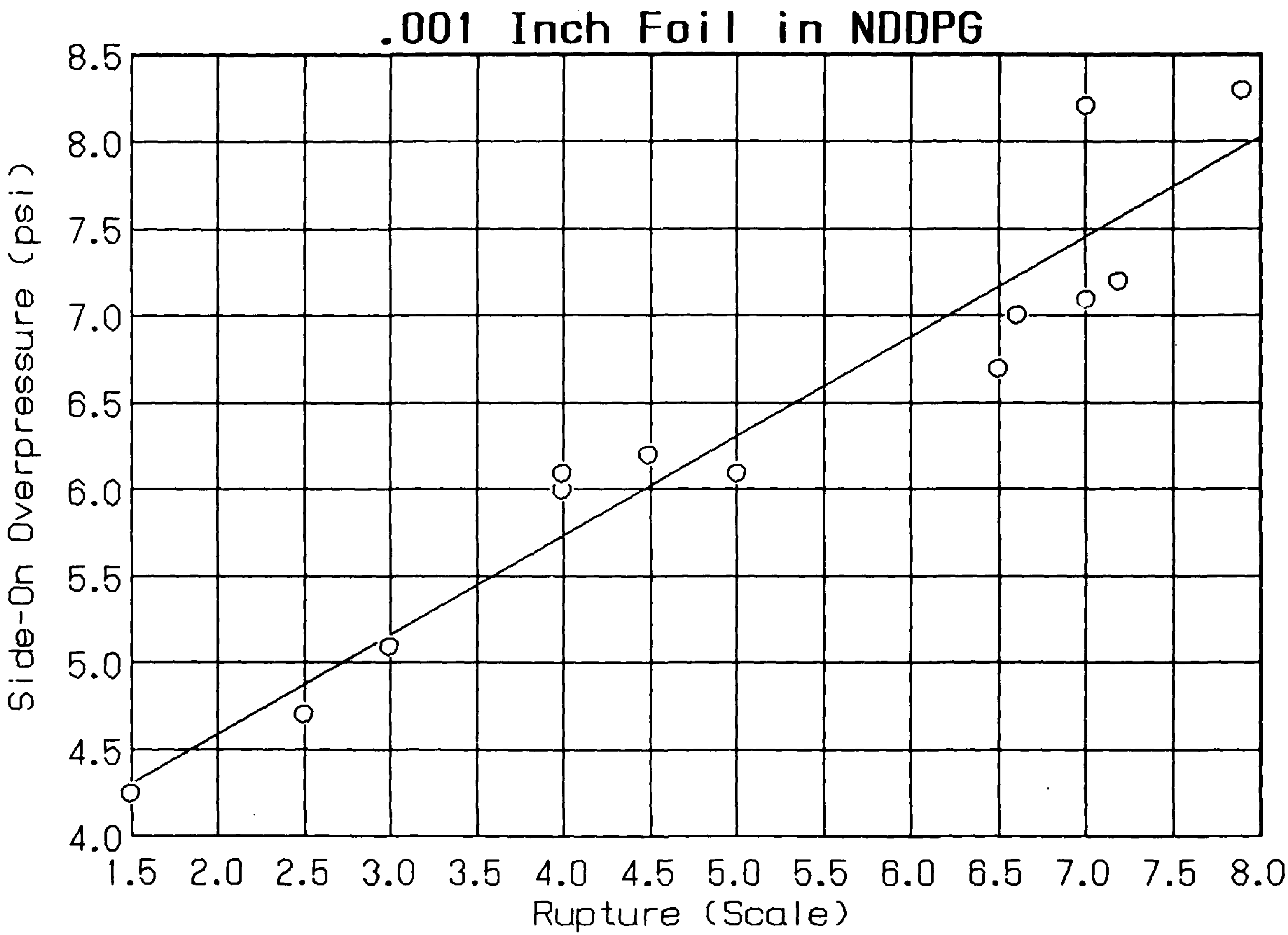

Figure 8. (U) CORRELATION CURVE C-2
Side-On Overpressure versus Rupture

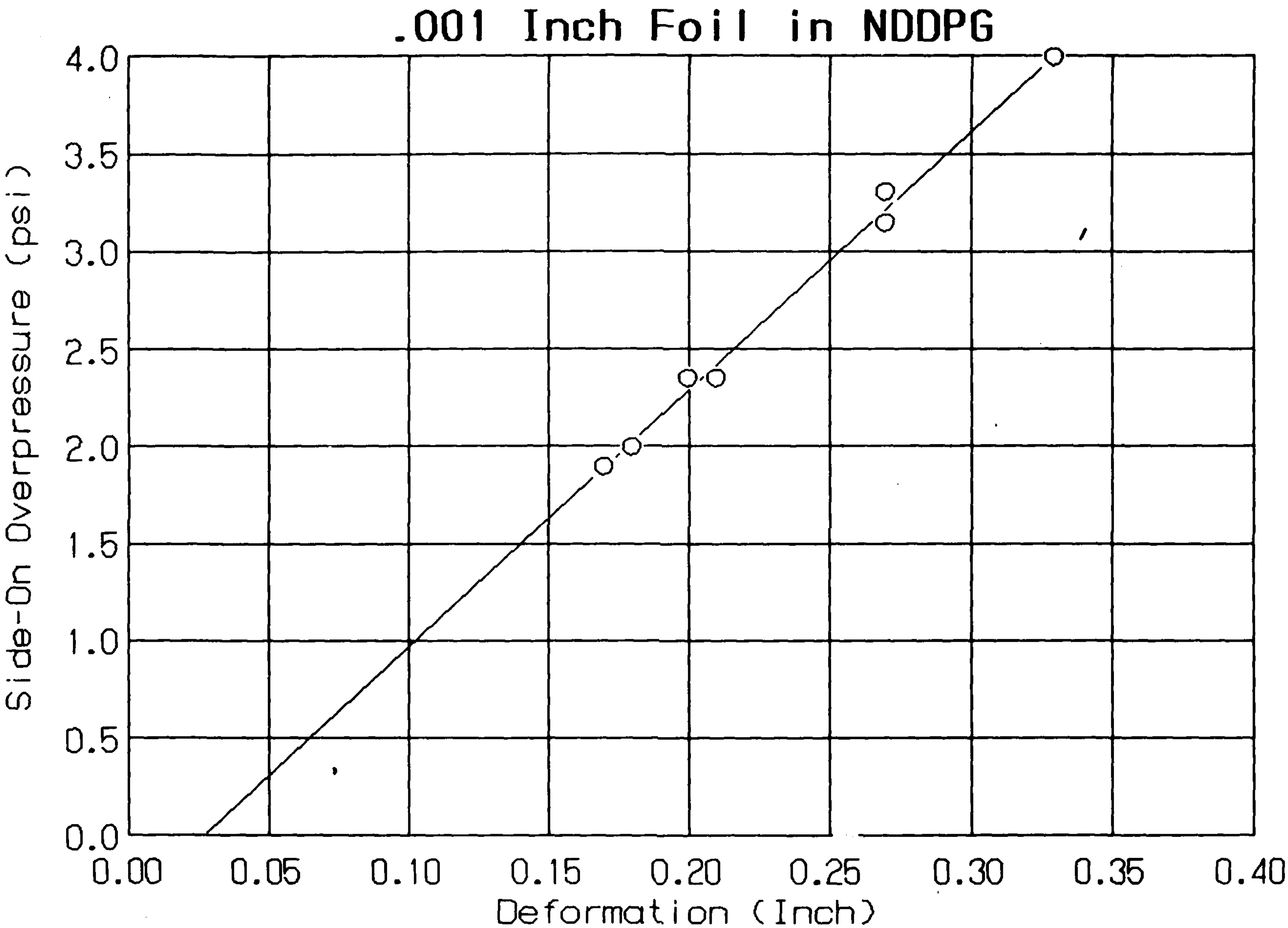

Figure 9. (U) CORRELATION CURVE C-3
Side-On Overpressure versus Deformation

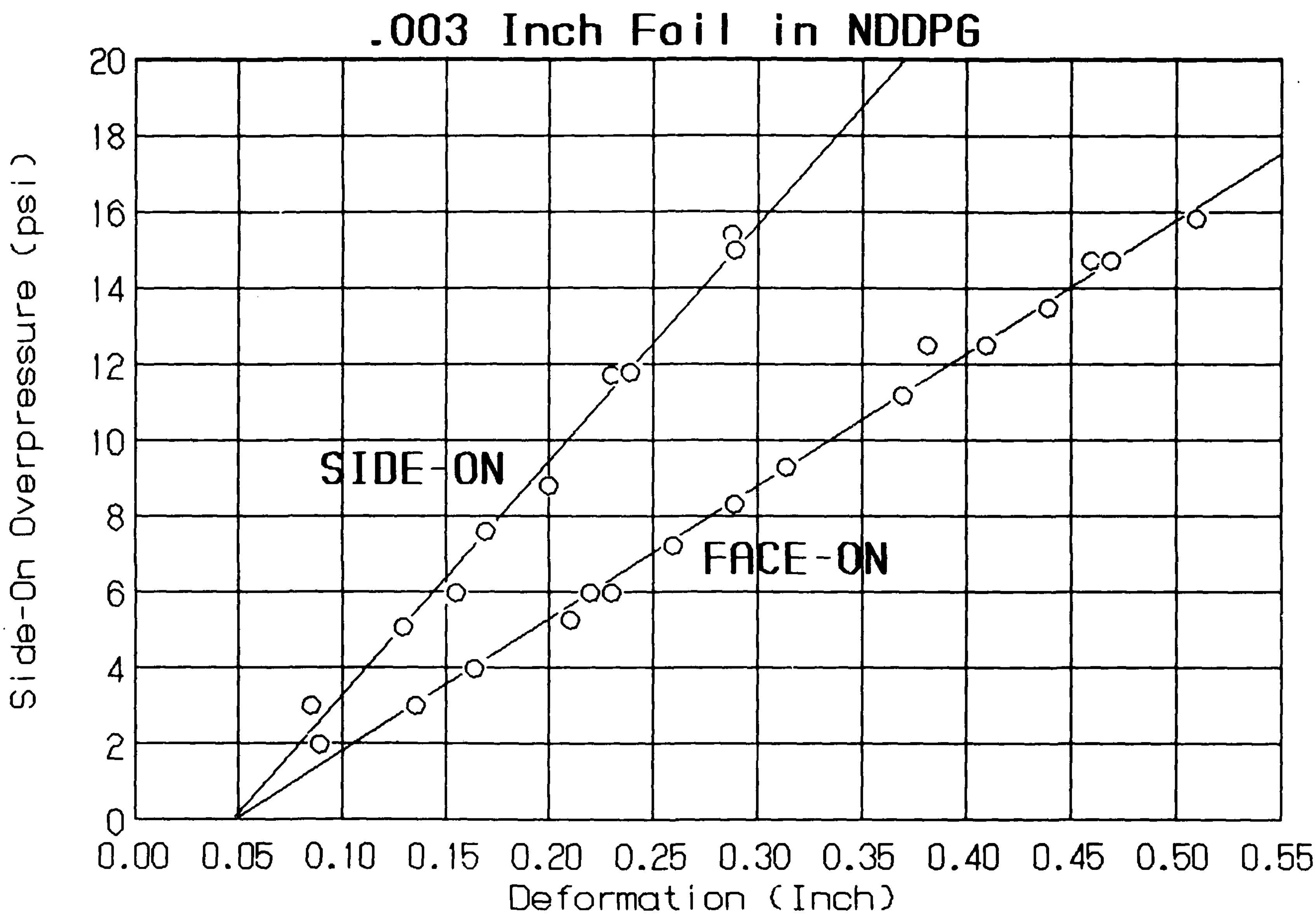

Figure 10. (U) CORRELATION CURVE D
Side-On and Face-On Overpressure versus Deformation

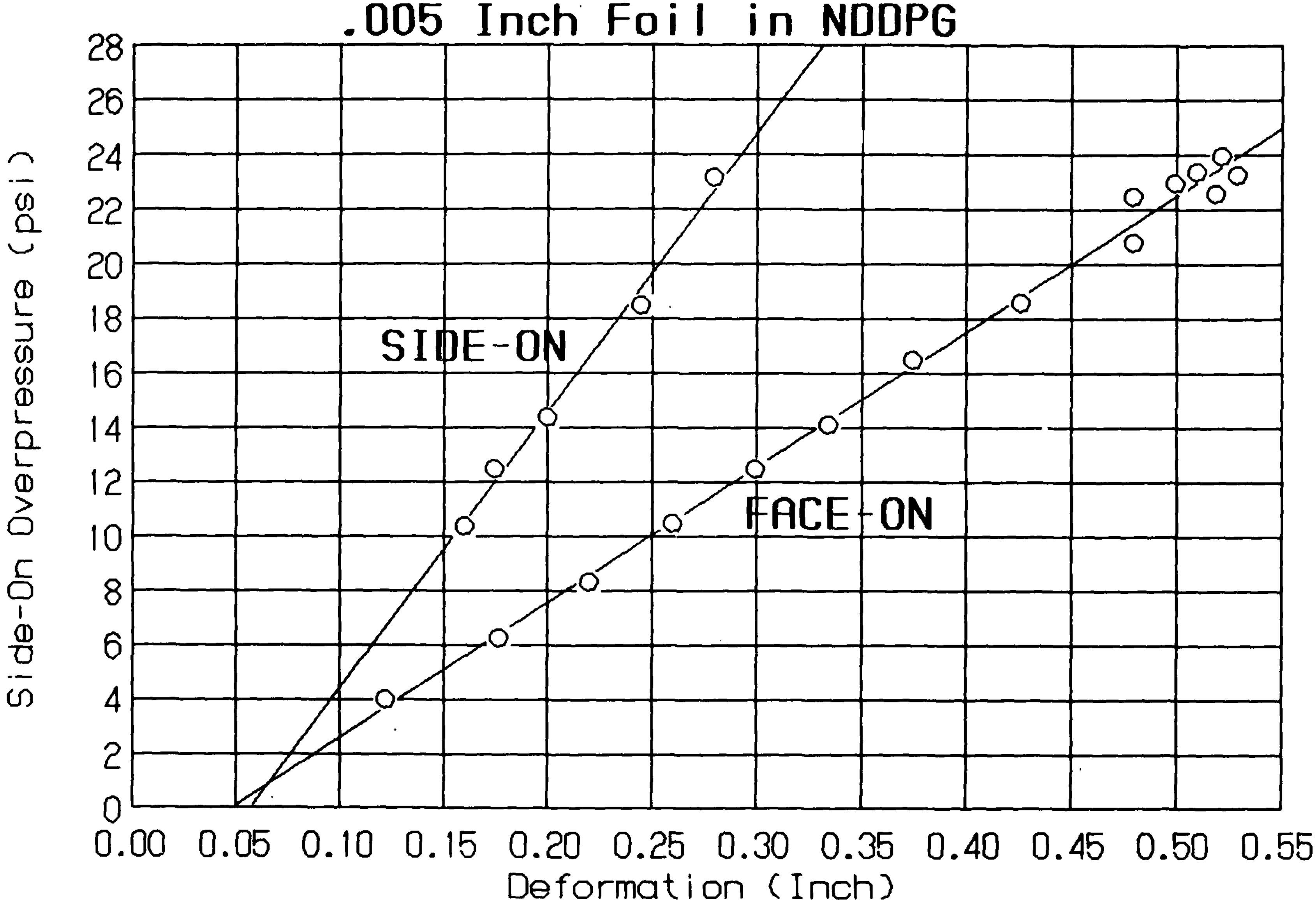

Figure 11. (U) CORRELATION CURVE E
Side-On and Face-On Overpressure versus Deformation

3.0 OPERATING INSTRUCTIONS: QUASI-STATIC DIAPHRAGM PRESSURE GAGE (QSDPG)

3.1 Selection of Foil. An estimate of expected maximum overpressure determines the appropriate foil thickness. Using previous experimental data, estimate an expected maximum overpressure. Select a calibration curve (Figure 14) that incorporates an overpressure range approximately 10 to 25 percent greater than the estimate. Install the foil correlated with the chosen calibration curve. Please note that any new foil must be pure, annealed aluminum and must be calibrated before using (1).

3.2 Installation of Foil. The appropriate thickness of foil is sandwiched between the pressure gage front and rear chambers (see Figure 12, end view, and Figure 13 for details). Remove the cover plate, which is distinguishable from the back plate by a one-inch shock attenuation pipe. Place Silastic 732RTV adhesive/sealant (or equivalent) on the top of the rear chamber plate. Attach the foil with the sealant, centering it over the chamber. When marking the foil with thickness information, test number, etc., use a permanent marker on a surface away from the exposed area of the foil. Place the cover plate over the foil, using no sealant; using a sharp instrument such as an awl or an ice pick, punch holes in the foil to align with the screw holes in the cover plate. Replace the screws, attaching the cover plate.

3.3 Attachment of Gage Housing to Gage Mount. The gage is mounted on a paddle-type gage mount for experimental use. Insert the screws completely through the gage housing and back cover plate before attaching the housing to the mount. Verify that the chamber behind the foil is covered by either the back plate or the gage-mount paddle. The back plate may be omitted when a solid-paddle gage mount is used.

3.4 Gage Orientation for Blast Experiment in a Compartment. The QSDPG can be oriented for compartmented detonation, explosive or shaped charge detonation, and impaction outside the compartment at one of its walls.

3.4.1 Small Charge Detonated Inside Compartment. The QSDPG permits omnidirectional orientation of the foil with respect to shock propagation inside a test compartment. Place the gage inside the compartment with the attenuation tube pointing in any direction.

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(1) A source is: International Foils
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3.4.2 Explosive or Shaped Charge Detonated or Impacting Outside Compartment. The QSDPG permits omnidirectional orientation of the foil with respect to shock propagation outside a test compartment at one of its walls. Place the gage inside the compartment with the attenuation tube pointing in any direction.

3.5 Auxiliary Equipment. Measuring peak quasi-static overpressure inside a compartment requires the use of a depth-gage micrometer and a recording form.

3.6 Deformation Measurement. Measuring peak quasi-static overpressure inside a compartment is a five-step process. Remove the cover plate, which contains the shock attenuation tube. Let air into the gage chamber by raising the foil at the narrow end of the chamber or by making a pinhole in the foil at the entrance area. If the foil is not convex, push the foil down to a configuration where permanent deformation is not altered. Position the micrometer on the foil at the large area of gage housing to reckon the maximum deformation depth or maximum opening. Measure depth (D) from the surface of the foil. Please note that no quasi-static pressure can be determined if the foil ruptures. Therefore, a pressure range should be determined that eliminates the potential for rupture.

3.7 Peak Quasi-Static Overpressure Values. Determining peak overpressure value for a given blast requires the use of an appropriate calibration curve. With reference to Figure 14, use the curve labeled with the corresponding thickness of foil used.

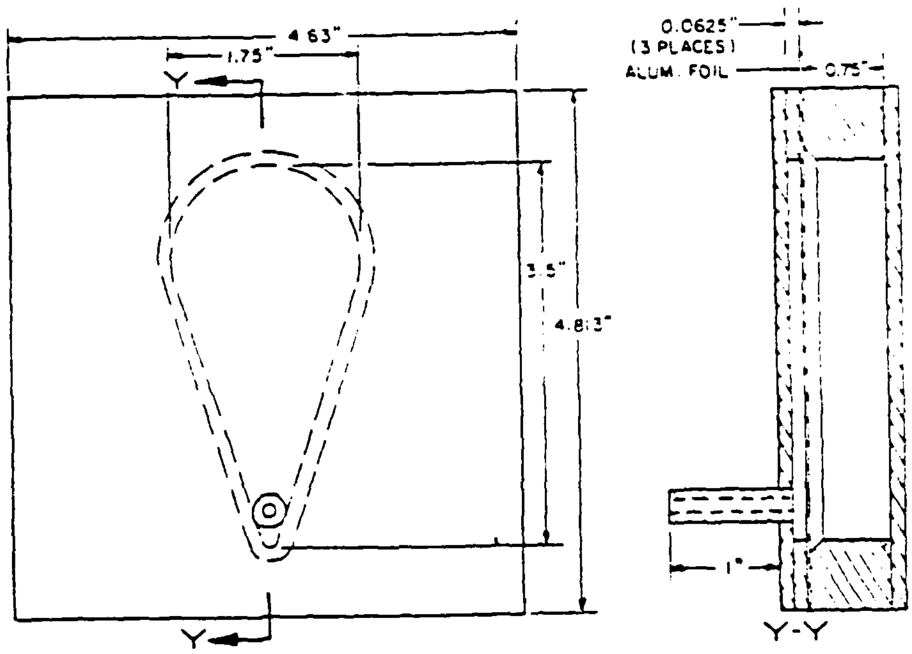

Figure 12. End View--Quasistatic Diaphragm Pressure Gage (QS-DPG).

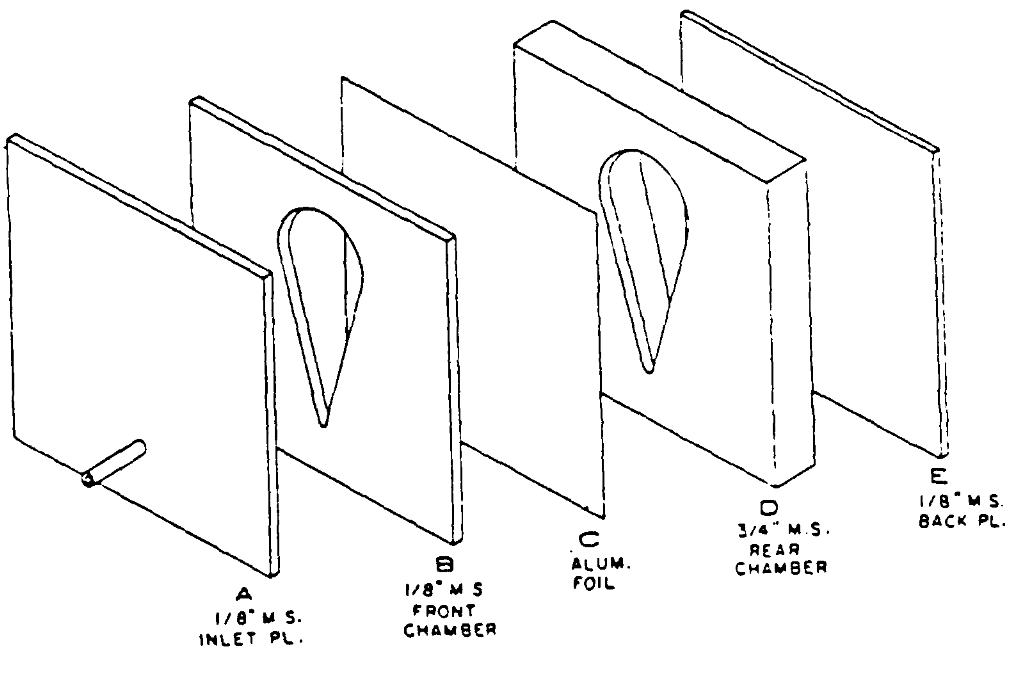

Figure 13. (U) Construction Plan View of the Quasistatic Diaphragm Pressure Gage (QS-DPG).

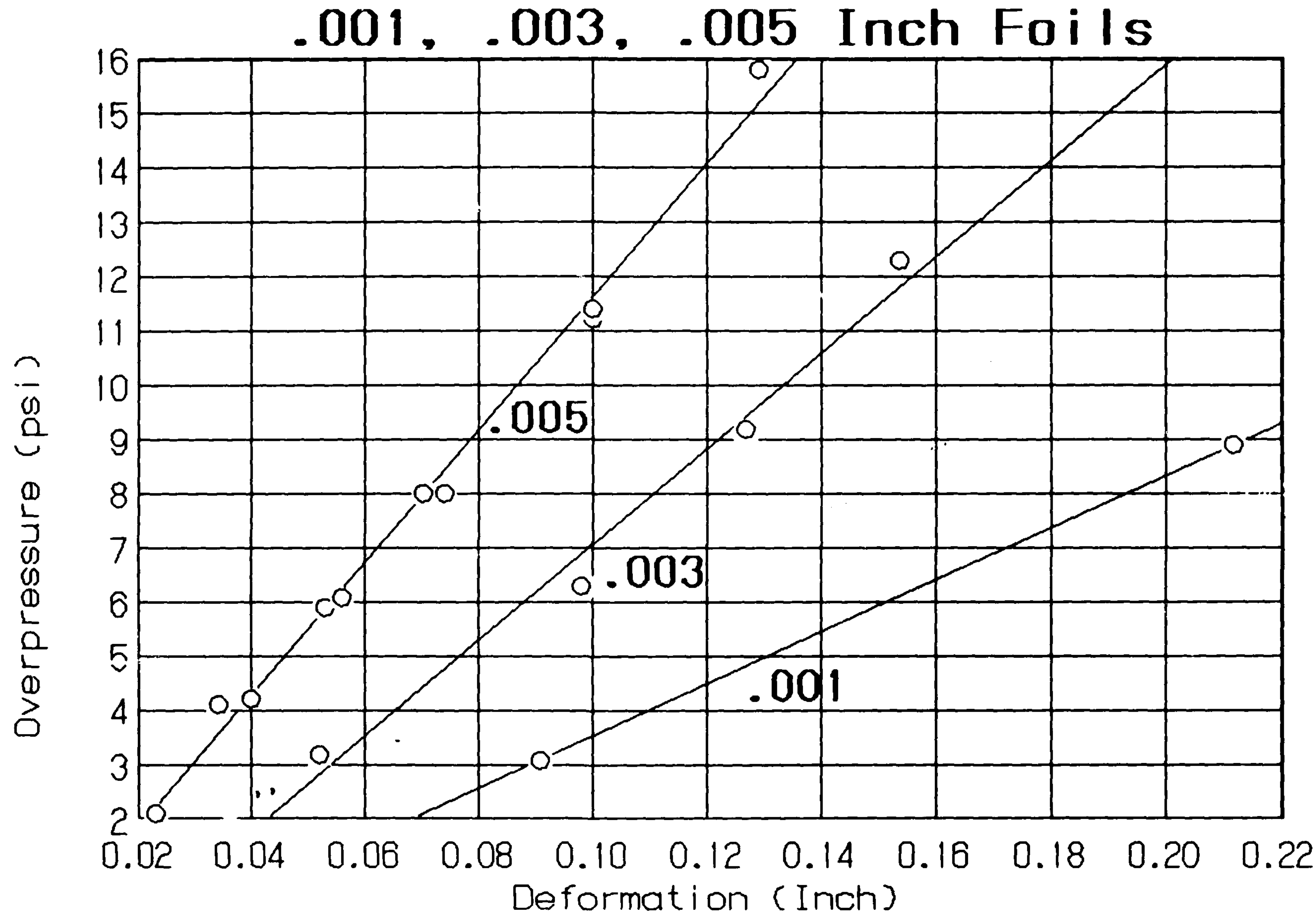

Figure 14. (U) CORRELATION CURVE QS-DPG
Overpressure versus Deformation

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